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Civil Tiltrotor Market Penetration Effects on Northeast Corridor Airport Delay

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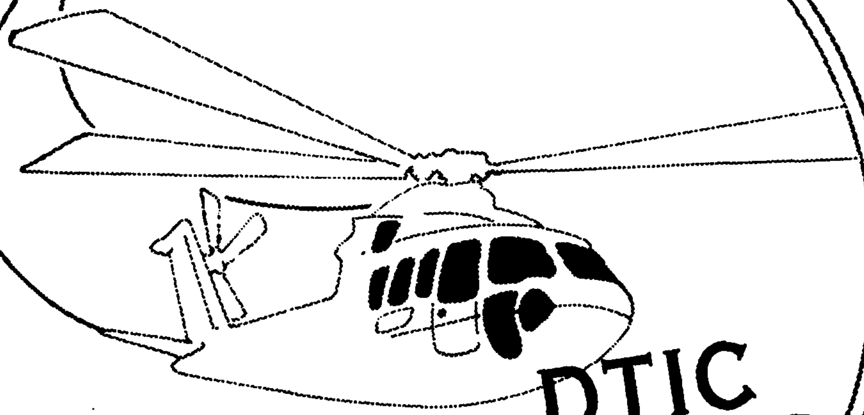

February 1994

FAA-AOR-100-94-001
DOT/FAA/CT-TN94/1

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Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN94/1 FAA-AOR-100-94-001	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Civil Tiltrotor Market Penetration - Effects on Northeast Corridor Airport Delay		5. Report Date: February, 1993
		6. Performing Organization Code: ACD-340
7. Author(s): Anny S. Cheung and Douglas Baart		8. Performing Organization Report No.: DOT/FAA/CT-TN94/1 FAA-AOR-100-94-001
9. Performing Organization Name and Address: Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.: F2006X
12. Sponsoring Agency Name and Address: DOT/Federal Aviation Administration Operations Research Service Washington, DC 20590		13. Type of Report and Period Covered: Technical Note
		14. Sponsoring Agency Code: AOR-100
15. Supplementary Notes		

16. Abstract

This report addresses the delay impacts resulting from replacing conventional aircraft services with civil tiltrotor (CTR) operations in the Northeast corridor at four CTR service levels. This analysis was conducted by using the National Airspace System Performance Analysis Capability (NASPAC) Simulation Modeling System (SMS). Cost of delay savings were derived by using the cost of delay module. The result of this study will be used by the Vertical Flight Program Office (ARD-30) in assessing the benefits of the CTR operations in the Northeast corridor.

17. Key Words: Civil Tiltrotor (CTR), corridor airports, feeder airports, Full Removal Scenario (FRS), Partial Removal Scenarios (PRS)		18. Distribution Statement: This document is available to, the public through the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report): Unclassified	20. Security Classif. (of this page): Unclassified	21. No. of Pages: 37	22. Price

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of Arturo Politano, and Hal True, AOR-100, and Stephanie Fraser of the MITRE Corporation.

Special thanks go to Arthur Pomerantz and John Chen of CTA INC. Arthur Pomerantz served as an overall consultant, and John Chen conducted the simulation runs for the study.

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EXECUTIVE SUMMARY

INTRODUCTION

This report documents the National Airspace System Performance Analysis Capability (NASPAC) simulation results of replacing the scheduled conventional flights with the Civil Tiltrotor (CTR) operations. The analysis of full removal scenarios (FRS), with the total removal of 1930 flights, was conducted by the MITRE Corporation.

The objective of this study is to analyze the delay benefit at 25, 50, and 75 percent of the FRS.

This report presents the results of National Airspace System Performance Analysis Capability (NASPAC) simulations in which Civil Tiltrotor (CTR) service replaced between 480 and 1930 flights in the Northeast corridor. The 1930 flights, described as full removal scenarios (FRS), were identified under contract NAS2-12393, and estimate the upper limit of possible CTR service. The MITRE Corporation analyzed the delay benefits to conventional aircraft at this level of CTR service.

The objective of this study is to estimate the system-wide and airport delay impacts of CTR service levels at 25, 50, and 75 percent of the FRS in the Northeast corridor.

This analysis was based on two major assumptions: (1) the conventional flights displaced by the CTR were not backfilled with new flights, thereby maintaining the same passenger demand; (2) CTR traffic operated independently on a non-interfering basis from conventional aircraft.

METHODOLOGY

This analysis was performed using the NASPAC Simulation Modeling System (SMS).

The identified, scheduled conventional flights, which represented the reduced demand, were removed from the Official Airline Guide (OAG).

This study was conducted using the NASPAC Simulation Modeling System (SMS).

The 1930 scheduled flights identified as candidates for CTR replacement represented the reduced demand for conventional flights. Those flights were removed from the Official Airline Guide (OAG). All removed scheduled flights were from the air traffic among the 7 corridor airports and 69 feeder airports (located within 500 miles of corridor airports).

The seven corridor airports used for this study are: Boston (BOS), Newark (EWR), Kennedy (JFK), La Guardia (LGA), Philadelphia (PHL), Washington (DCA), and Washington Dulles (IAD).

The seven corridor airports are: Bos (Boston Logan International Airport), EWR (Newark International Airport), JFK (John F. Kennedy International Airport), LGA (New York La Guardia Airport), PHL (Philadelphia International Airport), DCA (Washington National Airport), and IAD (Washington Dulles International Airport).

The analysis was based on two time frames (years 1990 and 2000). Six weather days were used for annualization. Two of the weather days (Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) were selected from the six days for detailed analysis.

The time frames used for this study were the years 1990 and 2000. Estimated annual results were computed for both time frames using the NASPAC weather annualization method. Six weather days were used to compute the annual result. Two of the weather days, an all-VFR (Visual Flight Rule) day and a worst-case IFR (Instrument Flight Rule) day were selected from the six weather days for detailed analysis.

The analysis focused on comparing the estimated simulation results between the baseline (no CTR replacement) and the four CTR service levels. Results of the four CTR service levels were also compared between themselves.

RESULTS

The simulation results showed significant delay reductions on both system and airport levels. Sixty-five percent of the FRS system delay reductions occurred at service level in year 2000.

The NASPAC simulation results showed significant reductions on system-wide and corridor airports delay.

The system-wide passenger arrival delay was reduced by as much as 19 percent at the FRS in year 2000. Sixty-five percent of the FRS delay reductions occurred at the 25 percent CTR service level. BOS, LGA and PHL recorded the largest delay reductions among the seven corridor airports.

The maximum total system cost of delay savings of 1.7 billion dollars (1992 dollars) occurred at the FRS for the year 2000.

The total annual system-wide cost of delay showed a savings of 0.6 billion dollars for year 1990, and 1.7 billion dollars for year 2000. The savings occurred at the FRS on 1992 dollars for both time frames.

The IFR day received most of the delay reductions with the CTR operations.

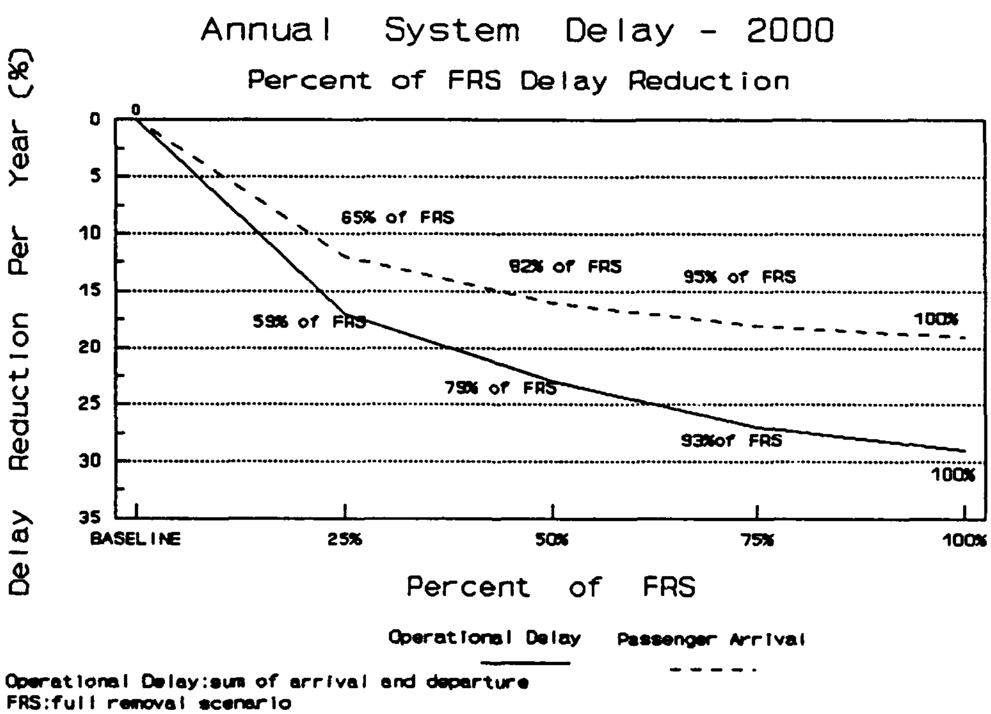
The IFR day produced a maximum of 37 percent system-wide delay reduction, and 97 percent delay reduction at LGA. These maximum delay reductions were achieved at the FRS for the year 2000.

The IFR day received the most delay reductions with the CTR operations when compared to the VFR day and the weather annualization.

CONCLUSIONS

FRS is not necessary for CTR service to provide relief to the congested airports in the Northeast corridor.

The analysis in this report shows that FRS is not necessary for CTR service to provide relief to the congested airports in the Northeast corridor. Sixty-five percent of the FRS delay benefits were achieved with only 25 percent of the FRS traffic levels. The figure below shows the system-wide percentage of FRS delay benefit achieved at the 25, 50, and 75 percent CTR service levels.



1. INTRODUCTION.

The use of Civil Tiltrotor (CTR) service is an alternative solution to the highly congested air traffic areas in the Northeast corridor. Several studies and research concerning CTR were conducted by BOEING and the MITRE Corporation. The MITRE Corporation conducted an "Analysis of Impacts of Civil Tiltrotor Service in the Northeast corridor Phase 1" [1] in 1991. A follow-on analysis, "Civil Tiltrotor Northeast corridor Delay Analysis (based on the Demand Scenario Described in "Civil Tiltrotor Missions and Applications Phase II: The Commercial Passenger Market") [2], was also conducted by the MITRE Corporation in 1993. From now on, the follow-on analysis is called the Phase II Delay Analysis.

This report documents the simulation results of CTR replacement of the conventional aircraft in the Northeast corridor performed by Federal Aviation Administration (FAA) Technical Center and is referred to as the Market Penetration Study. The Market Penetration Study is a follow-up analysis of MITRE's Phase II Delay Analysis. The Phase II Delay Analysis includes two scenarios, the baseline scenario, without CTR service, and full removal scenario (FRS), with CTR service replacing 1930 conventional flights in the Northeast corridor. The Market Penetration Study assesses the delay benefits of three partial removal scenarios (PRS). The results of MITRE's Phase II Delay Analysis are included in this report. Since a series of analyses on the potential benefits of CTR operations was already completed, it is assumed that the reader has some familiarity with the background of CTR service.

This project is sponsored and coordinated by the System Analysis Division (AOR-100) of the Operations Research Service. The client for this study is the Vertical Flight Program (ARD-30) of the Research and Development Service.

1.1 PURPOSE OF ANALYSIS.

Since CTR is a new form of air traffic service, the acceptance of this operation is uncertain. A sensitivity analysis of FRS is needed to evaluate the potential benefits of a less-than-full CTR service level. The purpose of this study was to assess system-wide and airport delay impacts of CTR service levels at 25, 50, and 75 percent in the Northeast corridor. The associated cost of delay savings were also computed to provide measurement of benefits of the CTR operations in the Northeast corridor.

1.2 SPECIAL TERMS.

Special terms and ideas used for this analysis are as follows:

a. Corridor Airports: The seven major airports located in the Northeast corridor are: BOS (Boston Logan International Airport), EWR (Newark International Airport), JFK (John F. Kennedy International Airport), LGA (New York La Guardia Airport), PHL (Philadelphia International Airport), DCA (Washington National Airport), and IAD (Washington Dulles International Airport).

b. Corridor Flights: Flights with both origin and destination within the Northeast corridor.

c. Feeder Airports: The 69 airports that feed the corridor airports located within 500 miles. A list of the feeder airports is in appendix A.

d. Feeder Flights: Flights with either origin or destination within the Northeast corridor.

e. Other Airports: Airports other than corridor and feeder airports.

f. Operational Delay (Technical Delay): Delay accrued by an aircraft waiting to use an air traffic control (ATC) system resource due to congestion.

g. Passenger Arrival Delay (Effective Arrival Delay): The difference between the time an aircraft arrives at its gate and its scheduled arrival time.

h. Full Removal Scenario (simulated by MITRE): A scenario in which a total of 1930 conventional flights identified by contract NAS2-12393 [3] as candidates for CTR replacement were removed and replaced by CTRs. The 1930 flights consisted of 248 (about 58 percent) and 1680 (about 75 percent) of the Official Airline Guide (OAG) scheduled corridor and feeder flights, respectively. Table 1 shows examples of the full removals of the conventional scheduled flights from the February 1990 OAG data.

TABLE 1. EXAMPLES OF FULL REMOVAL SCENARIO

Airport Pair	Number of Flights in the OAG Data	Number of Flights Replaced by CTR
BOS <--> IAD	12	6
BOS <--> PHL	46	22
DCA <--> BWI	13	11
EWR <--> BDL	25	17

I. PRS: Three scenarios, with part of the 1930 scheduled conventional flights to be replaced by CTR, were removed. The three PRS are:

25 percent CTR: About 25 percent of the 1930 flights were removed from the OAG scheduled flights.

50 percent CTR: About 50 percent of the 1930 flights were removed from the OAG scheduled flights.

75 percent CTR: About 75 percent of the 1930 flights were removed from the OAG scheduled flights.

j. Random Flight Removal (see section 2.6): The method of selecting flights to be removed from the OAG scheduled flights. The same method was applied to all PRS.

1.3 KEY ASSUMPTIONS.

This analysis was based on the assumption that the Northeast corridor CTR service will reduce demand for conventional air carrier service. The reduced demand was represented by removing the identified conventional flights from the OAG scheduled flights, and not backfilling the slots with conventional flights. Another key assumption of this analysis was that the CTR aircraft would operate independently, and not interfere with conventional aircraft. To accommodate the CTF flights, 12 vertiports would be built in the Northeast corridor: three in the Boston area, six in the New York area, two in the Washington, DC area, and one in Philadelphia. The CTR airspace and vertiports are not within the scope of this report and, therefore, will not be discussed.

2. METHODOLOGY.

This simulation study was conducted by using the National Airspace System Performance Analysis Capability (NASPAC) Simulation Modeling System (SMS). This section presents an overview of the NASPAC SMS and describes the methodology and scenario structure used for this analysis.

2.1 OVERVIEW OF NASPAC SMS.

The NASPAC SMS is a tool used to analyze the impact of proposed operational and capital improvement changes on the performance of the National Airspace System (NAS). It is an event-step simulation model that tracks the progress of aircraft as they compete for and use ATC resources. NASPAC simulates system-wide performance, and provides a quantitative basis for decision making related to system improvements and management. The model supports strategic planning by identifying air-traffic flow congestion problems and examining solutions. NASPAC analyzes the interactions among many components of the airspace system and the system's reaction to projected demand and capacity changes.

NASPAC is a macro-model used to estimate system-wide impacts of an ATC proposed change. Traffic profiles consist of scheduled and unscheduled arrivals and departures for 58 major airports. Scheduled demand is derived from the OAG and is used for predicting future growth. Unscheduled demand is derived from daily and hourly distributions taken from real world data (tower count). When using these distributions, the model randomly selects unscheduled flights for inclusion in the hourly airport arrival and departure demand. The projected traffic growth is provided by the FAA Terminal Area Forecasts (TAF) [4].

2.2 METHOD FOR ANALYSIS.

The time frames used for this analysis were the years 1990 and 2000. Estimated annual results were computed for both time frames using the NASPAC Weather Annualization [5] method. One Visual Flight Rules (VFR) day and one Instrument Flight Rules (IFR) day were selected from the six weather days that were used for annualization for both time frames. This enabled us to evaluate the effects reducing conventional flights in the Northeast corridor would have on different weather conditions. The selected VFR day was January 13, on which all of the seven corridor airports operated at 100 percent Visual Meteorological Conditions (VMC). The selected IFR day was December 22, on which all seven corridor airports operated below 100 percent VMC.

This analysis was based on the averaged results of three stochastic runs. The analysis focused on the following areas: corridor, feeder, and other airports. More emphasis was placed on the corridor airports. The baseline results were compared with the PRS. The results of the PRS were also compared among themselves. The associated cost of delay savings resulting from the simulations were computed using the Cost of Delay Module [6]. Comparisons of estimated annual system cost of delay savings were made among the CTR service levels.

Table 2 shows the designed structure for analysis. The X's represent the scenarios simulated for delay analysis. Each scenario was simulated for the six weather days with three stochastic runs for each day. A total of 180 simulations were conducted for the analysis.

TABLE 2. SCENARIO STRUCTURE FOR ANALYSIS

Year	No CTR	Percent (%) of CTR Replacement 25%	50%	75%	100%
1990	X	X	X	X	X
2000	X	X	X	X	X

2.3 NASPAC WEATHER ANNUALIZATION.

The MITRE Corporation developed a method for computing the estimated annual results of the NASPAC-based analysis. Six scenario days were selected as representative of varying levels of Instrument Meteorological Condition (IMC) and VMC across the 58 NASPAC airports. To compute the annual results, weighting factors for each of the scenario days were applied according to the frequency of occurrence of similar days in a year. Table 3 shows the weights applied to the six scenario days.

TABLE 3. WEIGHTING FACTORS FOR THE SIX WEATHER SCENARIOS

Percent(%) VMC	Scenario Day Chosen	Weighting Factor (No. Days/Year)
95% - 100%	January 13, 1990	80.00
90% - 95%	September 27, 1990	127.50
85% - 90%	May 16, 1990	86.25
80% - 85%	March 10, 1990	23.75
70% - 80%	March 31, 1990	17.50
< 70%	December 22, 1990	30.00

Note: January 13, 1990 and December 22, 1990 were selected as all VFR and IFR days, respectively. These two days were selected for detailed analysis.

2.4 COST OF DELAY MODULE.

The Cost of Delay Module was developed by the FAA Technical Center to be incorporated into the NASPAC SMS. This module addresses the savings that would be realized when changes are made to the ATC System. It translates delay into a cost metric to provide a better understanding of potential cost saving measures.

The Cost of Delay Module uses the latest data acquired from the Economic Analysis Branch (APO-220) as a means of determining operational and passenger costs. These costs include crew salaries, maintenance, fuel, equipment, depreciation, and amortization, and are reported by the airlines on a quarterly basis on Form 41 to the Department of Transportation. The data are aggregated by airlines and aircraft types, and used as a reference for the Cost of Delay Module. This information is divided into airborne and ground costs for each airline and aircraft type in which cost information is reported. Passenger

cost estimates were derived by using an FAA endorsed constant of $40.50 provided by the Office of Aviation Statistics, multiplied by the hourly delay absorbed by all of the passengers aboard the flight. The estimated number of passengers aboard each flight depends on aircraft type. APO-220 provided this information, which is listed in appendix B.

2.5 DATA FILES.

Since this study is a sensitivity analysis of MITRE's CTR Phase II Delay Analysis, many required data files were provided by MITRE. The OAG files, which are the key input files for this study, were developed by the FAA Technical Center using the random flights removal method (see section 2.6).

2.6 RANDOM FLIGHT REMOVAL.

A computer program was written to remove flights from the February 8, 1990 OAG-scheduled flights, while using a random number generator. The flights to be removed were selected randomly, while maintaining the same proportion of flights within the following groups for each PRS. A complete list of passengers and flights removals is in appendix B.

Group 1: Flights among the seven corridor airports (248 flights)
Group 2: Flights departing BOS for one of the feeder airports (219 flights)
Group 3: Flights departing DCA for one of the feeder airports (62 flights)
Group 4: Flights departing EWR for one of the feeder airports (152 flights)
Group 5: Flights departing IAD for one of the feeder airports (56 flights)
Group 6: Flights departing JFK for one of the feeder airports (59 flights)
Group 7: Flights departing LGA for one of the feeder airports (134 flights)
Group 8: Flights departing PHL for one of the feeder airports (156 flights)
Group 9: Flights departing one of the feeder airports for one of the corridor airports (844 flights)

3. RESULTS.

All annual system delay presented in this report was based on operational and passenger delay. The operational delay is the sum of departure and arrival delays. The passenger delay represented only the arrival delay. The airport delay represented the passenger arrival delay.

The simulation results are presented in the following seven sections.

3.1 ANNUAL SYSTEM DELAY.

The results of annual system delay showed significant reductions on both operational and passenger delay. The maximum operational delay reduction was 29 percent as compared to the no-CTR baseline case. The maximum passenger arrival delay reduction was 19 percent. These maximum delays occurred at FPC for the year 2000. These results show that CTR operations will benefit the NAS more with the projected future demand. Figures 1 and 2 show the annual system delay for the year 1990 and 2000 scenarios, respectively.

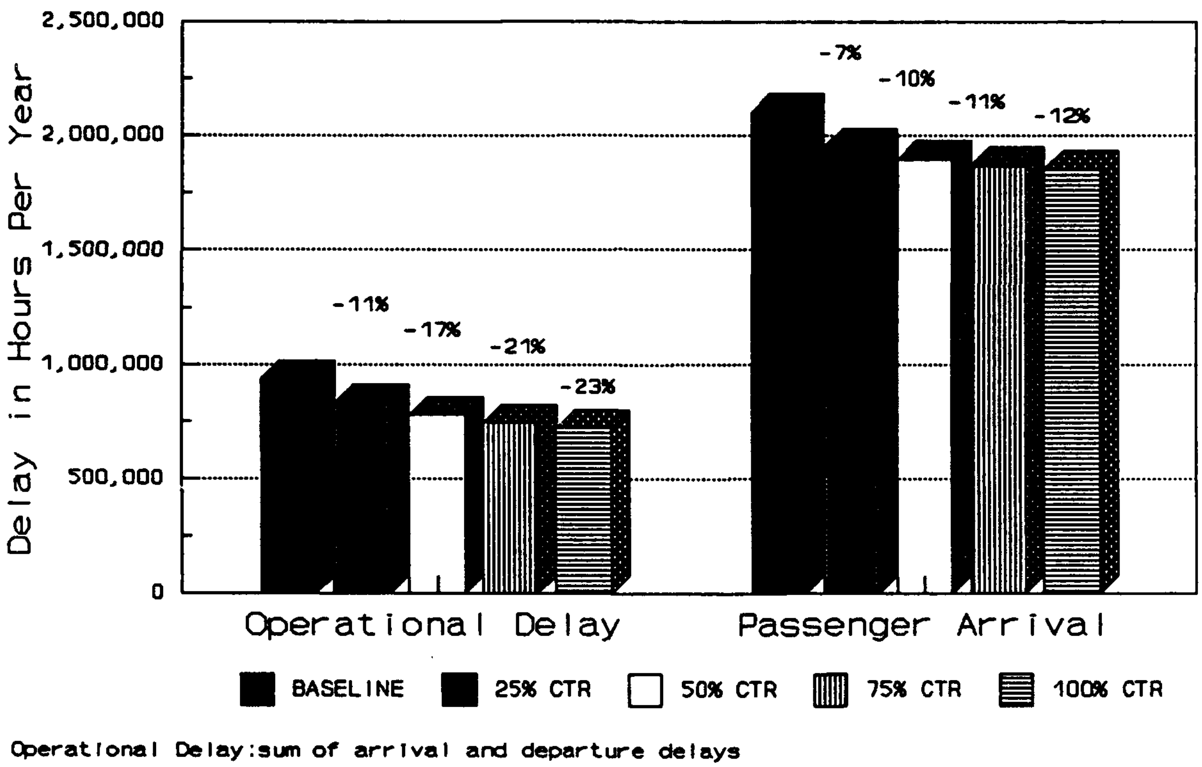


FIGURE 1. ANNUAL SYSTEM DELAY - 1990

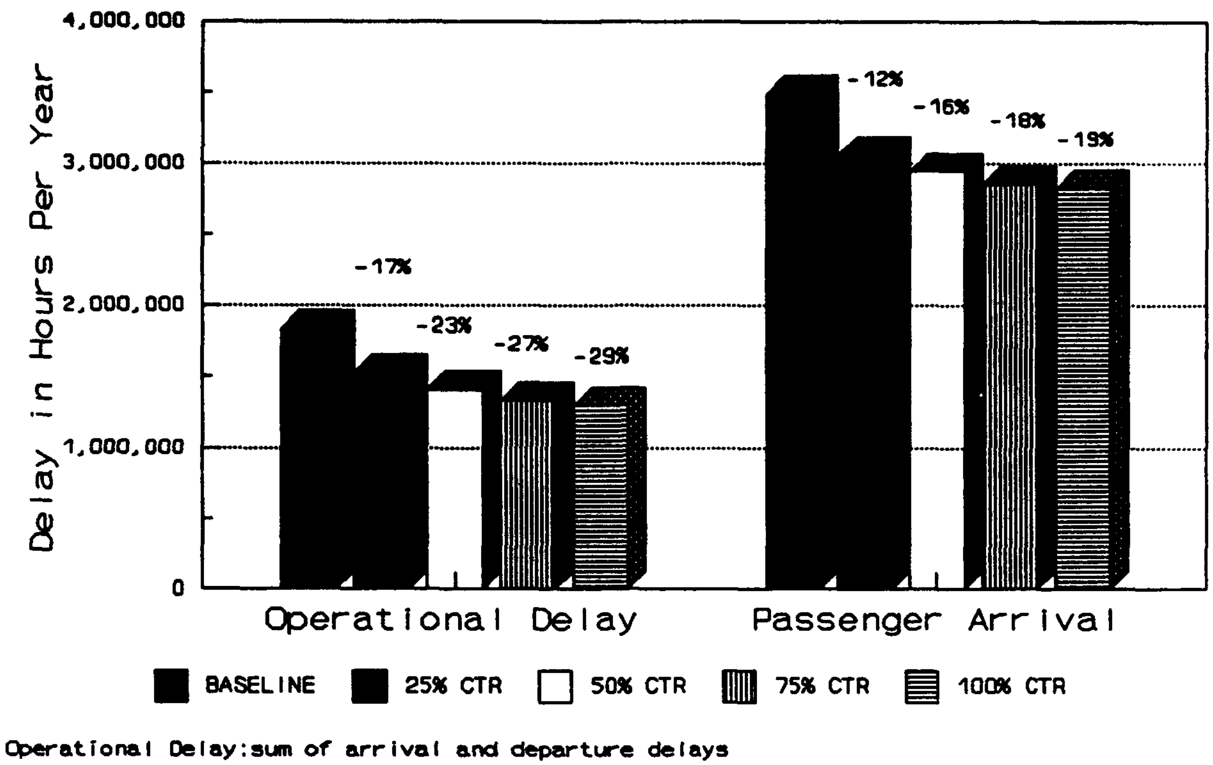


FIGURE 2. ANNUAL SYSTEM DELAY - 2000

3.2 ANNUAL CORRIDOR AIRPORTS DELAY.

The simulation results of annual corridor airports delay were organized by grouping the seven corridor airports into four metropolitan areas. The results indicated that the Boston area showed the largest reduction in delay with the introduction of CTR operations. The passenger arrival delay reduction for the Boston area was 85 percent for year 1990, and 92 percent for year 2000. These delay reductions occurred at the FRS for both time frames. Figures 3 and 4 show the 1990 delay for the four metropolitan areas in aircraft hours and delay reduction in percentages, respectively. Figures 5 and 6 present the year 2000 delay in the same format.

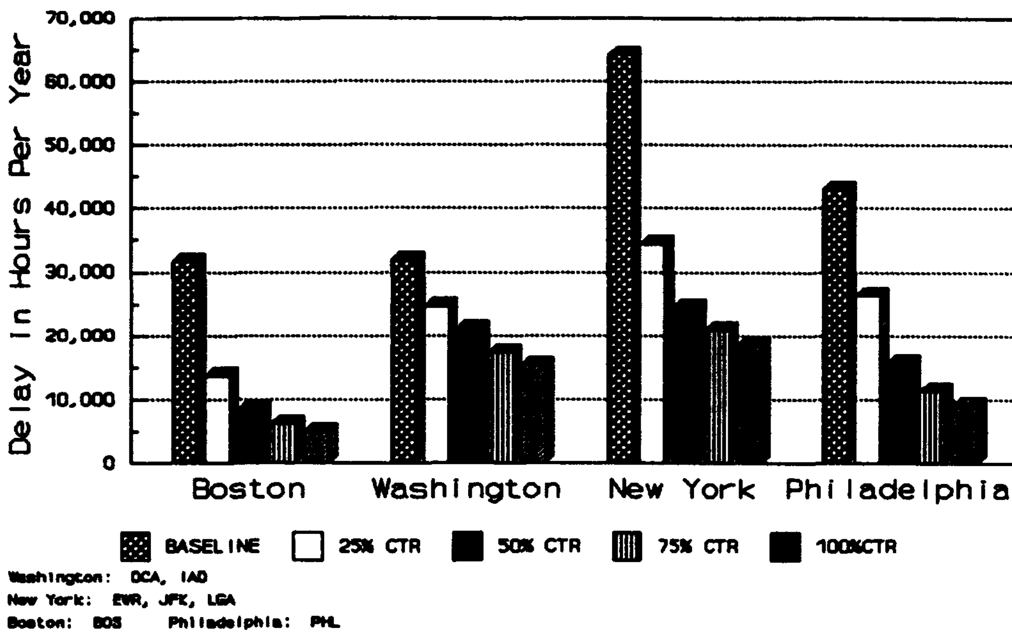


FIGURE 3. ANNUAL PASSENGER ARRIVAL DELAY BY METROPOLITAN AREA - 1990

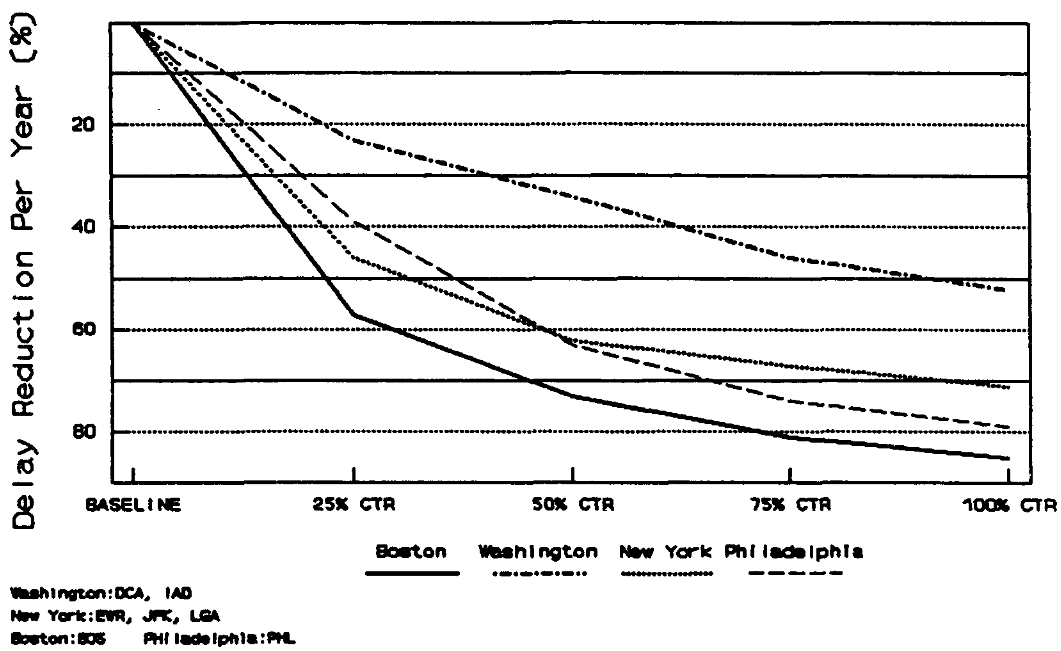


FIGURE 4. ANNUAL PASSENGER ARRIVAL DELAY REDUCTION BY METROPOLITAN AREA - 1990

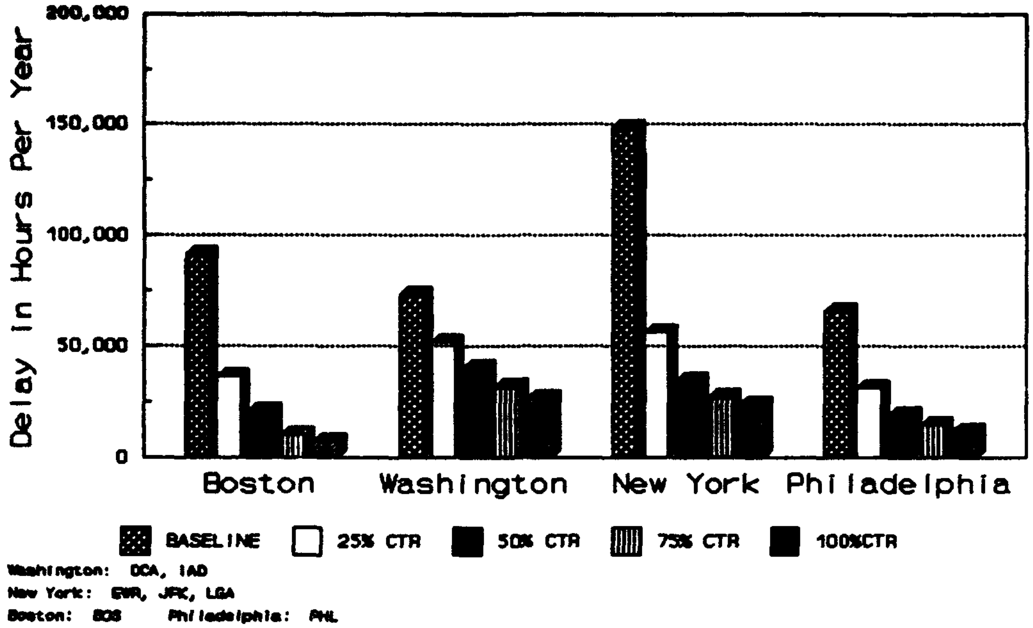


FIGURE 5. ANNUAL PASSENGER ARRIVAL DELAY BY METROPOLITAN AREA - 2000

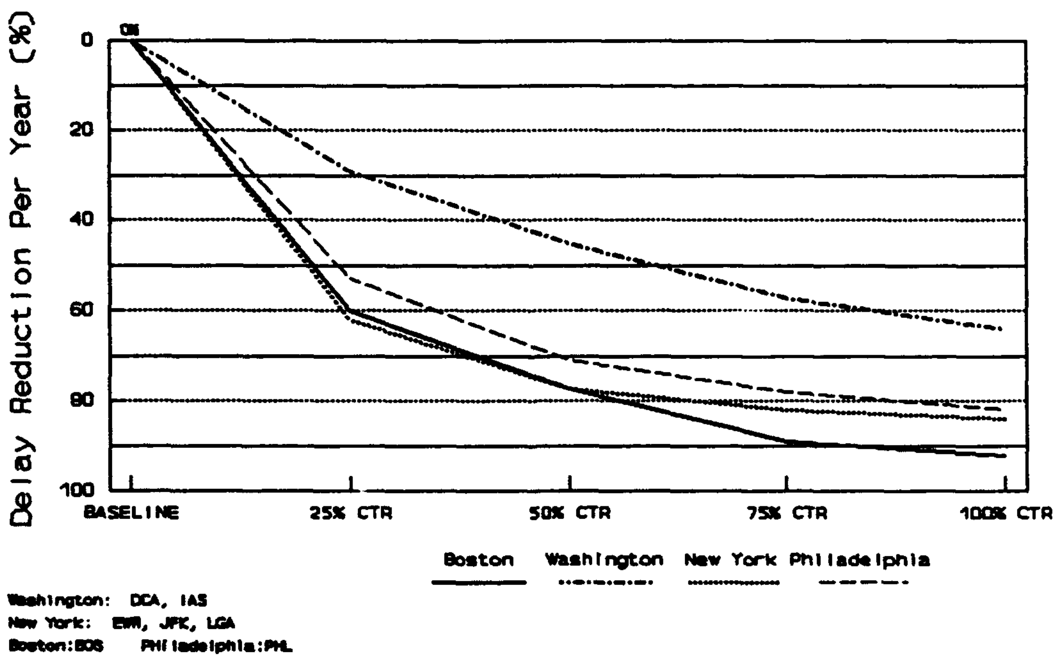


FIGURE 6. ANNUAL PASSENGER ARRIVAL DELAY REDUCTION BY METROPOLITAN AREA - 2000

Table 4 summarizes the individual corridor airports delay reduction. According to the simulation results, BOS, LGA, and PHL were the three airports that received the largest delay reduction. The 25 percent CTR scenario for both time frames achieved the largest incremental reduction in delay among the four CTR service levels.

TABLE 4. INDIVIDUAL CORRIDOR AIRPORT DELAY REDUCTION

Airport	25% CTR		50% CTR		75% CTR		100% CTR	
	1990	2000	1990	2000	1990	2000	1990	2000
BOS	57%	60%	73%	77%	81%	89%	85%	92%
DCA	30%	37%	41%	53%	53%	66%	59%	71%
IAD	10%	12%	21%	29%	31%	38%	38%	47%
EWR	46%	51%	62%	70%	68%	78%	71%	80%
JFK	13%	22%	24%	35%	32%	44%	39%	49%
LGA	60%	75%	77%	87%	81%	91%	84%	92%
PHL	39%	53%	63%	71%	74%	78%	79%	82%

Reduction in Annual Passenger Arrival Delay at Individual Corridor Airports

3.3 ANNUAL FEEDER AIRPORTS DELAY.

Ten of the 69 feeder airports were modeled as delay generating airports. The reductions in annual passenger arrival delay at these 10 airports are summarized in Table 5, with BDL, HPN and SYR showing substantial delay reductions. In general, the 25 percent CTR scenario for both time frames achieved the largest incremental delay reduction among the four CTR service levels.

TABLE 5. INDIVIDUAL FEEDER AIRPORT DELAY REDUCTION

AIRPORT	25% CTR		50% CTR		75% CTR		100% CTR	
	1990	2000	1990	2000	1990	2000	1990	2000
BDL	30%	41%	48%	64%	58%	76%	60%	77%
BWI	9%	19%	13%	25%	21%	31%	25%	29%
CLE	12%	15%	16%	18%	18%	21%	18%	19%
DTW	6%	11%	6%	17%	7%	21%	7%	21%
HPN	14%	275	22%	36%	25%	44%	29%	49%
ISP	9%	15%	16%	20%	18%	27%	21%	33%
PIT	4%	14%	8%	23%	9%	24%	12%	24%
RDU	17%	13%	13%	4%	17%	16%	23%	25%
SDF	9%	13%	8%	14%	14%	20%	12%	18%
SYR	14%	31%	21%	41%	25%	44%	26%	46%

Reduction in Annual Passenger Arrival Delay at Individual Feeder Airports

3.4 ANNUAL OTHER AIRPORTS DELAY.

For this analysis, seven other airports were modeled as delay-generating airports. The largest delay reduction of these airports occurred at Fort Lauderdale-Hollywood International Airport (FLL), Tampa International Airport (TPA), and Atlanta International Airport (ATL) at the FRS for both time frames. Table 6 summarizes the delay reduction for these other airports. The same pattern of results was found in the other airports delay analysis. The 25 percent CTR is the most beneficial scenario among the four CTR service levels, with the largest incremental delay reduction.

TABLE 6. INDIVIDUAL OTHER AIRPORT DELAY REDUCTION .

Airport	25% CTR		50% CTR		75% CTR		100% CTR	
	1990	2000	1990	2000	1990	2000	1990	2000
ATL	7%	9%	9%	9%	10%	18%	11%	17%
DEN	2%	6%	4%	9%	6%	9%	6%	13%
DFW	3%	2%	5%	8%	7%	8%	5%	12%
FLL	11%	15%	16%	22%	20%	25%	15%	26%
LAX	0%	2%	1%	4%	3%	5%	5%	5%
ORD	3%	5%	4%	6%	5%	8%	4%	8%
TPA	8%	11%	14%	19%	14%	20%	17%	26%

Reduction in Annual Passenger Arrival Delay at Individual Other Airports

3.5 SYSTEM DELAYS FOR VFR AND IFR DAYS.

The simulation results showed that CTR operations will benefit the IFR day (December 22) most for the year 2000. The passenger arrival delay was 37 percent at 100 percent CTR scenario for the year 2000. The maximum delay benefit for the VFR day (January 13) occurred at the 75 and 100 percent CTR scenarios in year 2000. Both scenarios achieved 12 percent reductions in delay. Figures 7 and 8 show the delay patterns for the VFR day and the IFR day, respectively.

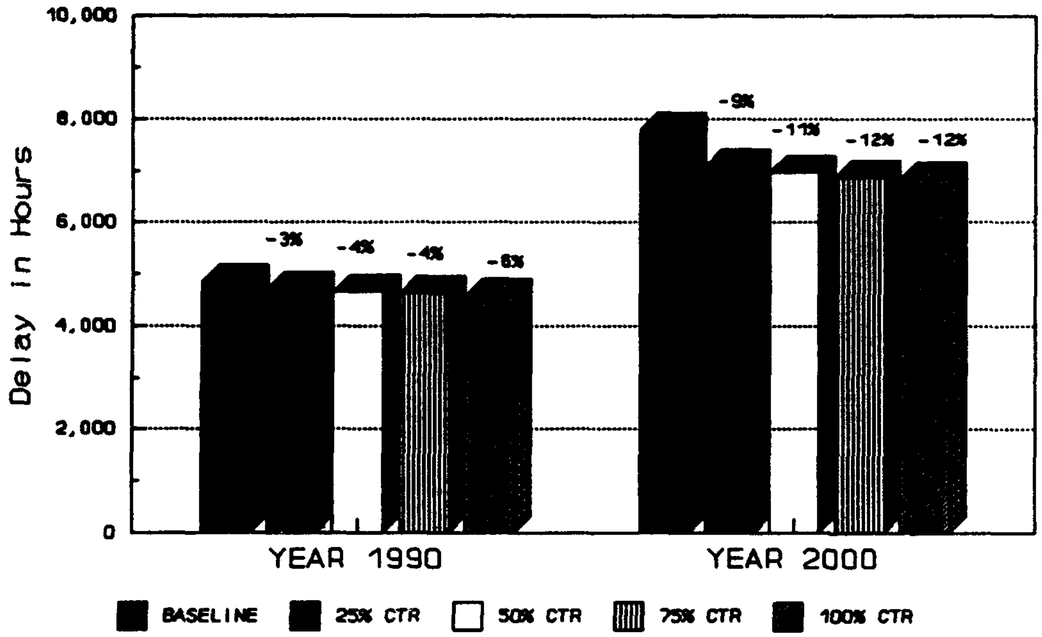


FIGURE 7. SYSTEM PASSENGER ARRIVAL DELAY - VFR DAY

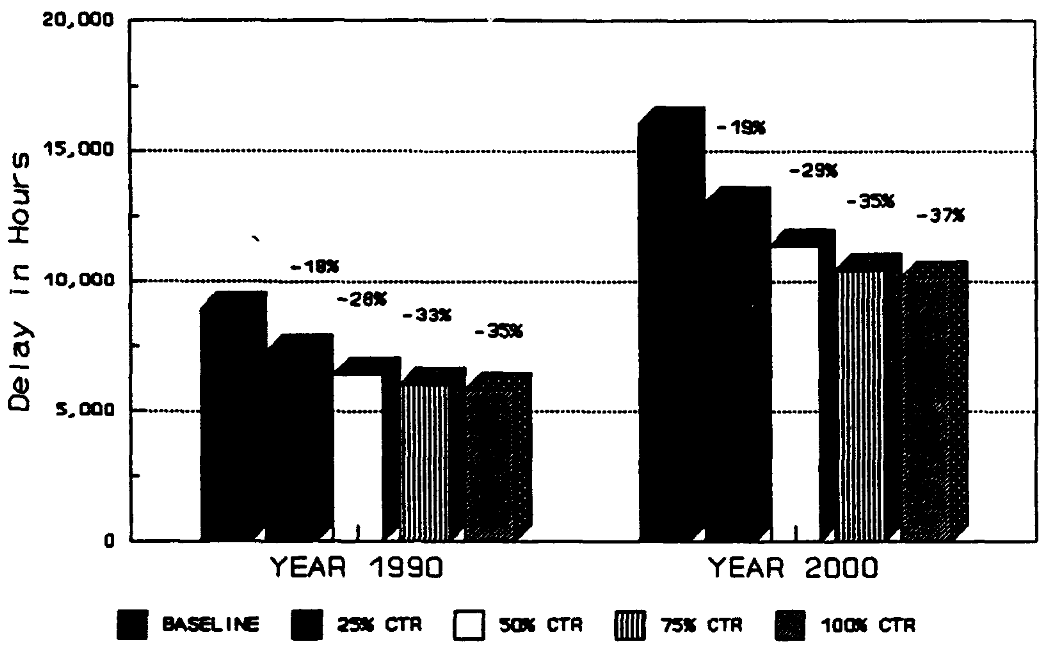


FIGURE 8. SYSTEM PASSENGER ARRIVAL DELAY - IFR DAY

3.6 CORRIDOR AIRPORTS DELAY FOR VFR AND IFR DAYS.

Tables 7 and 8 summarize the passenger arrival delay reduction at individual corridor airports for the VFR and IFR days, respectively. LGA received the largest delay benefit for both VFR and IFR days. The estimated delay reduction was 92 percent during a VFR day, and 97 percent during an IFR day for the year 2000.

TABLE 7. VFR DAY DELAY REDUCTION AT CORRIDOR AIRPORTS

Airport	25% CTR		50% CTR		75% CTR		100% CTR	
	1990	2000	1990	2000	1990	2000	1990	2000
BOS	35%	60%	50%	74%	60%	82%	69%	84%
DCA	13%	31%	16%	38%	21%	47%	28%	48%
IAD	5%	9%	18%	22%	28%	30%	36%	38%
EWR	42%	51%	57%	70%	64%	77%	66%	79%
JFK	7%	11%	5%	28%	7%	32%	12%	29%
LGA	55%	85%	66%	89%	70%	91%	77%	92%
PHL	35%	53%	49%	72%	54%	79%	60%	83%

Reduction in Passenger Arrival Delay at Individual Corridor Airports, VFR Day - January 13

TABLE 8. IFR DAY DELAY REDUCTION AT CORRIDOR AIRPORTS

Airport	25% CTR		50% CTR		75% CTR		100% CTR	
	1990	2000	1990	2000	1990	2000	1990	2000
BOS	54%	59%	69%	76%	81%	88%	87%	92%
DCA	43%	38%	63%	62%	80%	81%	86%	88%
IAD	16%	24%	28%	40%	40%	54%	43%	61%
EWR	53%	52%	75%	75%	85%	85%	87%	89%
JFK	11%	14%	24%	28%	34%	37%	41%	45%
LGA	62%	58%	90%	89%	94%	96%	95%	97%
PHL	37%	47%	72%	74%	85%	82%	91%	95%

Reduction in Passenger Arrival Delay at Individual Corridor Airports, IFR Day - December 22

3.7 ANNUALIZED COST OF SYSTEM DELAY.

The simulation results showed that the replacement of conventional air carrier service with CTR operations produced significant savings in delay cost. Figures 9 and 10 present the annual system-wide savings in delay cost for the years 1990 and 2000, respectively. The estimated total annual system-wide savings ranged from 0.4 to 0.6 billion dollars for the year 1990, and 0.9 to 1.7 billion dollars for the year 2000.

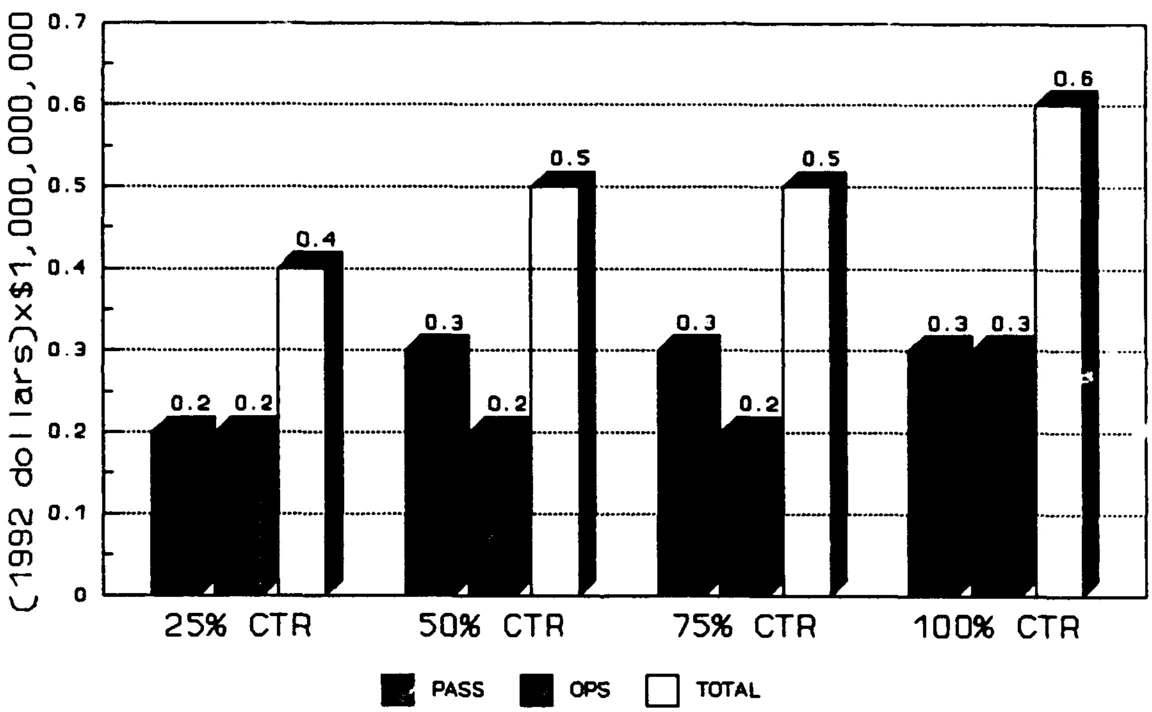


FIGURE 9. ANNUAL SYSTEM DELAY COST SAVINGS - 1990

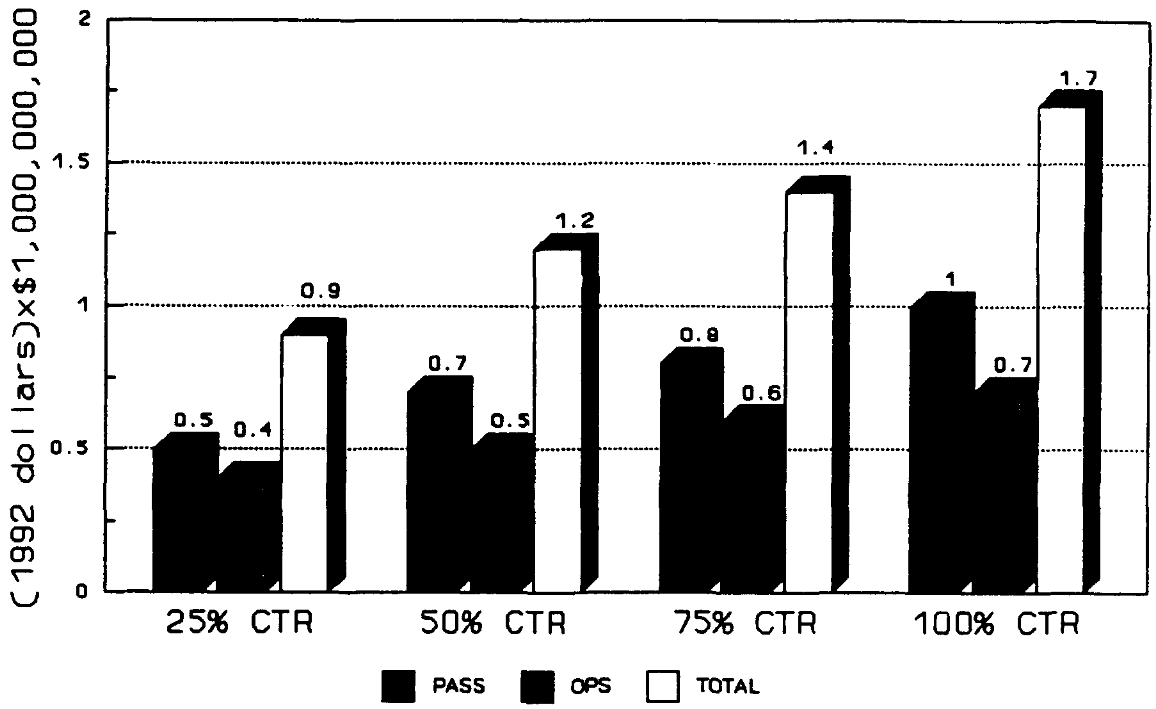


FIGURE 10. ANNUAL SYSTEM DELAY COST SAVINGS - 2000

4. CONCLUSIONS.

The simulation results suggest that, even at Partial Removal Scenarios (PRS) of Civil Tiltrotor (CTR) service, substantial delay savings may be realized. In fact, though the delay (in the simulation) decreased with increased CTR replacement of conventional flights, the largest incremental delay reduction occurred between the baseline and 25 percent CTR service level. The performance improvement associated with CTR introduction diminishes at higher levels of CTR market capture. The curves in figures 4 and 6 illustrate this trend for the Northeast corridor

airports. The effect is not limited to the corridor airports; it is also seen at the system level (figures 1 and 2).

The implications of this finding are that, given the near-saturation of airports in highly congested areas of the NAS, such as the Northeast corridor, even limited CTR market capture will yield significant benefits in the system. This result should also be factored into any cost-benefit calculation associated with the introduction of CTR service. For example, at 25 percent of FRS in the year 2000, the total cost savings are 0.9 billion dollars. Doubling the number of CTR flights (50 percent removal scenario) produces a savings of 1.13 billion dollars, an additional increase in savings of only 25 percent. Scenarios in which the demand-capacity imbalance was greater also showed the most improvement from the introduction of CTR service. Thus, the future-year (2000) scenarios (in which demand was assumed to increase) showed more delay reductions and cost savings than the 1990 scenarios. Similarly, the IFR weather day, in which capacity is reduced, showed more delay reduction than the predominantly-VFR day.

The reductions in system-wide passenger delay reflect not only the contribution of the corridor airports, but the rippling effects of delay these flights produce at airports outside of the Northeast corridor. Though the effect is obviously strongest at corridor and feeder airports, passenger arrival delay reductions were also seen at key airports that serve the Northeast corridor, such as Atlanta International Airport (ATL) and Dallas/Fort Worth International Airport (DFW) (table 6).

Conclusions drawn from this study should take into account the simplifying assumptions discussed in section 1.3, and the inherent limitations of the simulation methodology employed. Studies of feasibility and potential benefits of CTR service continue. A follow-on analysis that models CTR airspace has already begun.

5. REFERENCES.

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APPENDIX A

LIST OF 69 FEEDER AIRPORTS

The following list contains the airport names and locations of the 69 feeder airports.

LIST OF FEEDER AIRPORTS

LOCID	AIRPORT NAME	CITY, STATE
ABE	Allentown-Bethlehem-Easton Airport	Allentown, PA
ACK	Nantucket Memorial Airport	Nantucket, MA
ACY	Atlantic City International Airport	Atlantic City, NJ
AIY	Atlantic City Municipal/Bader Field Airport	Atlantic City, NJ
ALB	Albany County Airport	Albany, NY
AUG	Augusta State Airport	Augusta, ME
AVP	Wilkes-Barre/Scranton International Airport	Wilkes-Barre /Scranton, PA
BBX/ N67	Philadelphia Wings Field Airport	Philadelphia, PA
BDL*	Windsor Locks Bradley International Airport	Windsor Locks, CT
BDR	Bridgeport Igor I.Sigorsky Memorial Airport	Bridgeport, CT
BGM	Binghamton Edwin A. Link Field-Broome County Airport	Binghamton, NY
BGR	Bangor International Airport	Bangor, ME
BHB	Hancock County-Bar Harbor Airport	Bar Harbor, ME
BTV	Burlington International Airport	Burlington, VT
BUF	Greater Buffalo International Airport	Buffalo, NY
BWI*	Baltimore-Washington International Airport	Baltimore, MD
CHO	Charlottesville-Albemarle Airport	Charlottesville, VA
CHS	Charleston AFB/International Airport	Charleston, SC
CLE*	Cleveland-Hophins International Airport	Cleveland, OH
CMH	Port Columbus International Airport	Columbus, OH
CRW	Charleston Yeager Airport	Charleston, WV
DTW*	Detroit Metropolitan Wayne County Airport	Detroit, MI
ELM	Elmira/Corning regional Airport	Elmira, NY
ERI	Erie International Airport	Erie, PA
GON	Groton-New London Airport	Groton/ New London, CT
GSO	Greensboro Piedmont Triad International Airport	Greensboro, NC
HPN*	White Plains West Chester County Airport	White Plains, NY
HTO	East Hampton Airport	East Hampton, NY
HVN	Tweed-New Haven Airport	New Haven, CT
HYA	Hyannis Barnstable Municipal-Boardman/Polando Field Airport	Hyannis, MA
IPT	Williamsport-Lycoming County Airport	Williamsport, PA
ISP*	Islip Long Island MacArthur Airport	Islip, NY
ITH	Ithaca Tomphins County Airport	Ithaca, NY
LCI	Laconia Municipal Airport	Laconia, NH
LEB	Lebanon Municipal Airport	Lebanon, NH

LIST OF FEEDER AIRPORTS (CONCLUDED)

LOCID	AIRPORT NAME	CITY, STATE
LNS	Lancaster Airport	Lancaster, PA
LWB	Lewisburg Greenbrier Valley Airport	Lewisburg, WV
LYH	Lynchburg Municipal-Preston Glenn Field Airport	Lynchburg, VA
MDT	Harrisburg International Airport	Harrisburg, PA
MHT	Manchester Airport	Manchester, NH
MVY	Marthas Vineyard Airport	Vineyard Haven, MA
ORF	Norfolk International Airport	Norfolk, VA
ORH	Worcester Municipal Airport	Worcester, MA
PHF	Newport News/Williamsburg International Airport	Newport News, VA
PIT*	Greater Pittsburgh International Airport	Pittsburgh, PA
POU	Poughkeepsie Dutchess County Airport	Poughkeepsie, NY
PQI	Northern Maine Regional Airport at Presque Isle Airport	Presque Isle, ME
PVC	Provincetown Municipal Airport	Provincetown, MA
PVD	Providence Theodore Francis Green State Airport	Providence, RI
PWM	Portland International Jetport Airport	Portland, ME
RDG	Reading Regional/Carl A. Spaatz Field Airport	Reading, PA
RDU*	Raleigh-Durham International Airport	Raleigh/Durham, NC
RIC	Richmond International (Byrd Field) Airport	Richmond, VA
RKD	Rockland Knox County Regional Airport	Rockland, ME
ROA	Roanoke Regional/Woodrum Field Airport	Roanoke, VA
ROC	Greater Rochester International Airport	Rochester, NY
SBY	Salisbury-Wicomico County Regional Airport	Salisbury, MD
SCE/PSB	Philipsburg Mid-State Airport	Philipsburg, PA
SDF*	Louisville Standiford Field Airport	Louisville, KY
SYR*	Syracuse Hancock International Airport	Syracuse, NY
TTN	Trenton Mercer County Airport	Trenton, NJ
TYS	Knoxville McGhee Tyson Airport	Knoxville, TN
YHZ	Halifax, N.S., International Airport	Halifax, N.S.
YOW	Ottawa, Ont., International Airport	Ottawa, Ont.
YQI	Yarmouth, N.S., Airport	Yarmouth, N.S.
YSJ	Saint John, N.B., Airport	Saint John, N.B.
YTZ	Toronto Island, Ont., Airport	Toronto Island, Ont.
YUL	Montreal, Que., Dorval International Airport	Montreal, Que.
YYZ	Toronto, Ont., Lester B. Pearson International Airport	Toronto, Ont.

* Delay Generating Airports

APPENDIX B

REMOVAL DATA FOR FOUR CTR SERVICE LEVELS

This appendix contains the flights and operations removed from the February 8, 1990 OAC (Official Airline Guide) scheduled flights for four CTR service levels. The removals of flights and operations were performed by using the random flights removal method (Section 2.6). Information on the reduction of passengers was based on the Office of Airline Statistics, O.D. Survey of 1992.

REDUCTION OF PASSENGERS AND OPERATIONS AT FOUR CTR SERVICE LEVELS FEEDER AIRPORTS

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
ABE	47	11	308	26	537	37	628	49
ACK	102	6	141	12	177	17	252	28
ACY	22	1	69	8	121	12	172	21
AIY	33	3	110	10	154	14	220	20
ALB	968	41	1525	63	1934	94	2490	123
AUG	21	7	27	9	36	12	45	15
AVP	183	7	252	17	255	18	421	24
BDL	116	15	459	40	792	68	1136	88
BDR	102	10	234	20	348	32	514	44
BGM	39	7	75	13	132	23	207	33
BGR	152	8	420	17	681	24	812	27
BHB	3	1	12	4	15	5	24	8
BTV	103	10	192	22	213	26	267	38
BUF	130	3	384	7	766	13	770	15
BWI	813	22	1177	34	1486	51	1929	65
CHO	48	2	72	3	144	6	216	9
CHS	0	0	0	0	0	0	2	1
CLE	0	0	2	1	4	2	7	3
CMH	0	0	2	1	2	1	2	1
CRW	14	6	125	9	180	12	240	14
CYHZ	0	0	0	0	102	3	136	4
CYOW	0	0	0	0	0	0	4	2
CYQI	9	1	27	3	27	3	36	4
CYSJ	18	2	36	4	54	6	54	6
CYUL	61	4	95	5	138	7	172	8
DTW	365	6	703	14	1049	21	1279	25
ELM	24	8	90	16	120	19	162	26
ERI	9	1	36	4	45	5	72	8
GON	27	5	60	10	75	13	99	17
GSO	8	4	12	6	14	7	19	9
HPN	346	18	613	39	839	55	1004	69
HTO	11	1	33	3	55	5	66	6
HVN	21	3	146	4	670	12	834	18
HYA	102	6	159	11	219	17	279	23

REDUCTION OF PASSENGERS AND OPERATIONS AT FOUR CTR SERVICE LEVELS FEEDER AIRPORTS (Continued)

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
IPT	30	3	127	8	127	8	130	9
ISP	151	15	224	23	369	39	590	58
ITH	332	7	362	15	374	19	429	31
LCI	0	0	4	2	6	3	8	4
LEB	17	7	37	15	76	22	103	32
LNS	4	2	10	5	32	6	54	7
LWB	9	1	9	1	9	1	9	1
LYH	66	3	110	5	132	6	176	8
MDT	447	17	882	37	1102	54	1311	68
MHT	201	13	384	27	932	44	1655	74
MVY	42	7	54	11	93	17	153	23
N67	18	6	80	24	132	36	179	49
ORF	177	9	474	16	535	24	695	29
ORH	643	11	789	19	1432	30	1697	37
PHF	82	7	126	9	261	19	325	24
PIT	0	0	3	1	8	3	8	3
POU	141	4	158	11	194	17	205	22
PQI	15	2	27	3	42	5	57	7
PSB	123	6	147	7	264	12	342	16
PVC	4	2	10	5	12	6	12	6
PVD	484	16	965	33	1468	55	1866	71
PWM	31	11	149	30	428	52	476	67
RDG	148	8	200	12	224	13	274	16
RDU	52	3	55	4	148	9	185	14
RIC	133	10	148	13	231	22	318	28
RKD	3	1	3	1	3	1	6	2
ROA	144	5	239	10	296	13	347	14
ROC	377	4	1129	11	1506	15	1758	18
SBY	27	3	36	4	72	8	94	9
SDF	0	0	0	0	2	1	2	1
SYR	286	6	1226	18	1469	22	2016	33
TTN	0	0	44	2	44	2	44	2
TYS	0	0	0	0	9	3	18	6
YTZ	45	5	90	10	108	12	126	14
YYZ	244	9	423	17	571	25	642	28
TOTALS	8373	422	16320	844	24077	1264	30881	1682

REDUCTION OF PASSENGERS AND OPERATIONS AT FOUR CTR SERVICE LEVELS
CORRIDOR AIRPORTS

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
BOS	4045	154	8043	292	12112	447	15701	601
DCA	2462	63	4713	119	7431	183	10225	244
EWR	3991	92	7428	180	11816	264	14896	347
IAD	959	32	1815	56	2586	93	3645	127
JFK	1807	33	3938	73	4750	100	6028	129
LGA	2919	94	6051	188	9538	292	12768	391
PHL	1202	78	2662	184	3476	257	4579	339
TOTALS	17385	546	34651	1092	51709	1636	67844	2178

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS
BY AIRPORT PAIR - CORRIDOR AIRPORTS

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
BOS <-> DCA	596	9	1254	18	2043	29	2607	37
BOS <-> EWR	306	5	510	8	977	15	1125	17
BOS <-> IAD	173	2	173	2	357	4	584	6
BOS <-> JFK	368	4	526	6	607	7	850	10
BOS <-> LGA	1053	13	2635	32	4093	50	5227	64
BOS <-> PHL	405	7	883	15	994	17	1252	22
DCA <-> EWR	426	7	692	12	958	17	1224	22
DCA <-> LGA	1053	13	1944	24	3240	40	4868	60
EWR <-> IAD	68	1	272	3	272	3	350	4
IAD <-> PHL	57	1	114	2	114	2	241	4
JFK <-> PHL	0	0	162	2	162	2	162	2
TOTALS	4505	62	9165	124	13817	186	18490	248

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS
BY AIRPORT PAIR - FEEDER AIRPORTS

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
BOS <-> ABE	4	2	4	2	8	4	8	4
BOS <-> ACK	24	1	57	5	63	7	126	14
BOS <-> ACY	0	0	12	1	12	1	24	2
BOS <-> ALB	84	17	107	22	194	41	251	52
BOS <-> AUG	21	7	27	9	36	12	45	15
BOS <-> BDL	9	3	78	9	126	15	132	17
BOS <-> BDR	48	2	96	4	144	6	216	9

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS
BY AIRPORT PAIR - FEEDER AIRPORTS (CONTINUED)

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
BOS <-> BGM	12	1	12	1	15	2	39	4
BOS <-> BGR	27	7	45	14	56	19	62	21
BOS <-> BHB	3	1	12	4	15	5	24	8
BOS <-> BTV	98	8	176	16	197	20	245	30
BOS <-> BUF	0	0	2	1	5	2	5	2
BOS <-> BWI	3	1	3	1	3	1	3	1
BOS <-> CYHZ	0	0	0	0	102	3	136	4
BOS <-> CYOW	0	0	0	0	0	0	4	2
BOS <-> CYQI	9	1	27	3	27	3	36	4
BOS <-> CYSJ	18	2	36	4	54	6	54	6
BOS <-> CYUL	27	3	27	3	36	4	36	4
BOS <-> HPN	283	9	466	18	640	28	754	35
BOS <-> HYA	102	6	156	10	159	11	213	15
BOS <-> ISP	76	5	104	8	210	17	392	31
BOS <-> ITH	0	0	6	2	9	3	12	4
BOS <-> LCI	0	0	4	2	6	3	8	4
BOS <-> LEB	10	4	30	12	64	17	82	24
BOS <-> MDT	2	1	4	2	10	5	12	6
BOS <-> MHT	32	5	44	10	62	18	116	31
BOS <-> MVY	36	5	39	6	69	9	123	13
BOS <-> ORF	4	2	4	2	4	2	4	2
BOS <-> PQI	15	2	27	3	42	5	57	7
BOS <-> PVC	4	2	10	5	12	6	12	6
BOS <-> PVD	24	1	48	2	59	3	59	3
BOS <-> PWM	22	8	107	16	240	30	279	42
BOS <-> RIC	2	1	4	2	4	2	4	2
BOS <-> RKD	3	1	3	1	3	1	6	2
BOS <-> ROC	2	1	2	1	2	1	4	2
BOS <-> SYR	0	0	41	2	41	2	127	5
BOS <-> YYZ	139	5	241	8	312	11	346	12
DCA <-> ABE	2	1	52	4	52	4	52	4
DCA <-> AIY	0	0	33	3	66	6	88	8
DCA <-> ALB	24	2	105	4	108	5	170	6
DCA <-> BDL	0	0	34	1	80	3	83	4
DCA <-> BDR	24	2	48	4	60	5	96	8
DCA <-> BGM	0	0	0	0	24	2	36	3
DCA <-> BUF	0	0	0	0	0	0	2	1
DCA <-> BWI	44	4	66	5	106	8	161	11
DCA <-> CHS	0	0	0	0	0	0	2	1
DCA <-> CRW	6	3	15	4	17	5	26	6
DCA <-> DTW	67	1	67	1	67	1	67	1
DCA <-> GSO	0	0	2	1	2	1	2	1
DCA <-> HPN	36	4	81	9	90	10	126	14
DCA <-> ISP	36	4	54	6	72	8	90	10
DCA <-> LWB	9	1	9	1	9	1	9	1

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS BY AIRPORT PAIR - FEEDER AIRPORTS (CONTINUED)

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
DCA <-> MDT	48	2	48	2	72	3	102	6
DCA <-> ORF	44	4	88	8	143	13	176	16
DCA <-> PHF	11	2	11	2	75	7	77	8
DCA <-> PIT	0	0	3	1	3	1	3	1
DCA <-> ROA	18	2	36	4	45	5	45	5
DCA <-> SBY	18	2	27	3	54	6	76	7
DCA <-> SDF	0	0	0	0	2	1	2	1
DCA <-> TTN	0	0	44	2	44	2	44	2
EWR <-> ABE	15	5	146	8	277	11	292	16
EWR <-> AIY	33	3	77	7	88	8	132	12
EWR <-> ALB	509	7	902	16	1158	20	1298	26
EWR <-> AVP	131	3	146	8	149	9	280	12
EWR <-> BDL	9	3	155	11	289	15	545	19
EWR <-> BDR	12	4	15	5	24	8	33	11
EWR <-> BGM	9	3	9	3	21	7	30	10
EWR <-> BGR	125	1	375	3	625	5	750	6
EWR <-> BUF	0	0	0	0	2	1	2	1
EWR <-> BWI	625	5	875	7	1000	8	1250	10
EWR <-> CYUL	0	0	34	1	34	1	34	1
EWR <-> DTW	65	1	130	2	318	5	383	6
EWR <-> ELM	6	2	21	7	24	8	30	10
EWR <-> GON	9	3	15	5	21	7	27	9
EWR <-> GSO	4	2	4	2	4	2	4	2
EWR <-> HVN	3	1	128	2	634	8	762	10
EWR <-> ITH	250	2	256	4	259	5	274	10
EWR <-> MDT	36	5	54	11	84	14	90	16
EWR <-> MHT	129	3	262	8	764	13	1397	22
EWR <-> MVY	0	0	6	2	9	3	12	4
EWR <-> ORF	0	0	0	0	2	1	4	2
EWR <-> ORH	628	6	753	7	1381	13	1631	15
EWR <-> PIT	0	0	0	0	2	1	2	1
EWR <-> POU	0	0	0	0	0	0	3	1
EWR <-> PVD	64	6	198	10	456	17	638	24
EWR <-> PWM	0	0	0	0	125	1	125	1
EWR <-> RDU	0	0	0	0	0	0	4	2
EWR <-> RIC	2	1	2	1	6	3	10	5
EWR <-> ROC	250	2	625	5	877	8	1002	9
EWR <-> SYR	129	3	506	7	631	8	756	9
EWR <-> YTZ	45	5	90	10	108	12	126	14
EWR <-> YYZ	102	3	170	5	238	7	272	8
IAD <-> ABE	22	1	66	3	132	6	176	8
IAD <-> CHO	48	2	72	3	144	6	216	9
IAD <-> CRW	0	0	102	2	153	3	204	4
IAD <-> DTW	49	1	201	4	300	6	397	8
IAD <-> ISP	9	3	9	3	21	7	24	8

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS
BY AIRPORT PAIR - FEEDER AIRPORTS (CONTINUED)

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
IAD <-> LYH	66	3	110	5	132	6	176	8
IAD <-> MDT	51	1	150	4	174	5	246	8
IAD <-> N67	0	0	0	0	22	2	33	3
IAD <-> PHF	44	2	88	4	132	6	176	8
IAD <-> PSB	72	3	72	3	120	5	144	6
IAD <-> RDG	72	3	72	3	72	3	96	4
IAD <-> RDU	3	1	6	2	18	6	24	8
IAD <-> RIC	96	4	96	4	144	6	216	9
IAD <-> ROA	126	3	201	5	249	7	300	8
IAD <-> TYS	0	0	0	0	9	3	18	6
IAD <-> YYZ	3	1	12	4	21	7	24	8
JFK <-> ACY	0	0	3	1	3	1	6	2
JFK <-> ALB	201	7	228	9	234	11	480	19
JFK <-> BDL	14	2	75	8	126	13	152	15
JFK <-> BGM	0	0	3	1	3	1	3	1
JFK <-> BUF	125	1	375	3	750	6	750	6
JFK <-> BWI	88	6	132	9	233	15	327	20
JFK <-> ISP	12	1	12	1	12	1	12	1
JFK <-> MDT	211	3	446	7	446	7	470	8
JFK <-> ORF	125	1	375	3	375	3	500	4
JFK <-> POU	137	2	150	7	180	10	182	11
JFK <-> PVD	276	4	449	7	488	11	626	14
JFK <-> RIC	0	0	0	0	4	2	4	2
JFK <-> ROC	125	1	502	5	627	6	752	7
JFK <-> SYR	125	1	500	4	500	4	752	7
LGA <-> ACK	78	5	84	7	114	10	126	14
LGA <-> ALB	150	8	183	12	240	17	291	20
LGA <-> BDL	81	6	114	10	165	20	216	30
LGA <-> BGM	15	2	39	4	51	5	75	7
LGA <-> BTV	5	2	13	5	13	5	19	7
LGA <-> BUF	2	1	4	2	6	3	8	4
LGA <-> BWI	2	1	2	1	2	1	2	1
LGA <-> CMH	0	0	2	1	2	1	2	1
LGA <-> CRW	2	1	2	1	4	2	4	2
LGA <-> CYUL	34	1	34	1	68	2	102	3
LGA <-> DTW	60	1	177	3	177	3	177	3
LGA <-> ELM	12	4	12	4	15	5	24	8
LGA <-> GSO	2	1	2	1	4	2	6	3
LGA <-> HTO	11	1	33	3	55	5	66	6
LGA <-> HYA	0	0	3	1	60	6	66	8
LGA <-> ITH	3	1	9	3	15	5	27	9
LGA <-> LEB	7	3	7	3	12	5	21	8
LGA <-> MDT	72	3	75	4	123	6	150	8
LGA <-> MHT	40	5	78	9	104	12	134	17
LGA <-> MVY	6	2	9	3	15	5	18	6

REDUCTION OF PASSENGERS AND FLIGHTS AT FOUR CTR SERVICE LEVELS BY AIRPORT PAIR - FEEDER AIRPORTS (CONCLUDED)

	25% CTR		50% CTR		75% CTR		100% CTR	
Airport Pair	Pass	Flts	Pass	Flts	Pass	Flts	Pass	Flts
LGA <-> ORF	2	1	2	1	4	2	4	2
LGA <-> ORH	15	5	36	12	51	17	66	22
LGA <-> POU	4	2	8	4	14	7	20	10
LGA <-> PVD	120	5	270	14	465	24	543	30
LGA <-> PWM	9	3	42	14	63	21	72	24
LGA <-> RDU	49	2	49	2	130	3	157	4
LGA <-> RIC	0	0	2	1	2	1	2	1
LGA <-> ROA	0	0	2	1	2	1	2	1
LGA <-> SYR	32	2	179	5	229	6	281	8
PHL <-> ABE	4	2	40	9	68	12	100	17
PHL <-> ACY	22	1	54	6	106	10	142	17
PHL <-> AVP	52	4	106	9	106	9	141	12
PHL <-> BDL	3	1	3	1	6	2	8	3
PHL <-> BDR	18	2	75	7	120	13	169	16
PHL <-> BGM	3	1	12	4	18	6	24	8
PHL <-> BTV	0	0	3	1	3	1	3	1
PHL <-> BUF	3	1	3	1	3	1	3	1
PHL <-> BWI	51	5	99	11	142	18	186	22
PHL <-> CLE	0	0	2	1	4	2	7	3
PHL <-> CRW	6	2	6	2	6	2	6	2
PHL <-> DTW	125	2	129	4	187	6	255	7
PHL <-> ELM	6	2	57	5	81	6	108	8
PHL <-> ERI	9	1	36	4	45	5	72	8
PHL <-> GON	18	2	45	5	54	6	72	8
PHL <-> GSO	2	1	4	2	4	2	7	3
PHL <-> HPN	27	5	66	12	109	17	124	20
PHL <-> HVN	18	2	18	2	36	4	72	8
PHL <-> IPT	30	3	127	8	127	8	130	9
PHL <-> ISP	18	2	45	5	54	6	72	8
PHL <-> ITH	79	4	91	6	91	6	116	8
PHL <-> LNS	4	2	10	5	32	6	54	7
PHL <-> MDT	27	2	105	7	193	14	241	16
PHL <-> MHT	0	0	0	0	2	1	8	4
PHL <-> N67	18	6	80	24	110	34	146	46
PHL <-> ORF	2	1	5	2	7	3	7	3
PHL <-> PHF	27	3	27	3	54	6	72	8
PHL <-> PIT	0	0	0	0	3	1	3	1
PHL <-> PSB	51	3	75	4	126	7	198	10
PHL <-> RDG	76	5	128	9	152	10	178	12
PHL <-> RIC	33	4	44	5	71	8	82	9
PHL <-> SBY	9	1	9	1	18	2	18	2
PHL <-> SYR	0	0	0	0	68	2	101	4
TOTALS	8373	422	16320	844	24077	1264	30881	1682

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